~~F.A.~~ ~~E.S.~~ ~~DWB~~ ~~R.H.~~

Rec'd 5/7/70
from J.S. Krammes (PSWFF,RES)

THE EFFECTS OF LOGGING ROAD CONSTRUCTION ON INSECT DROP INTO A SMALL COASTAL STREAM

by

Lloyd J. Hess

A Thesis

Presented to

The Faculty of Humboldt State College

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

December, 1969

Approved by the Master's Thesis Committee

Roger A Barnhart Chairman

Approved for the Graduate Study Committee

TABLE OF CONTENTS

ACKNOWLEDGEMENT

Because my part in this project was purely analytical, I would like to acknowledge those people who collected the data for my analysis. Mr. James Andrews, Mr. Brian Eddie, and Mr. Michael McCurdy were in charge of the insect collections in 1966 and 1968 and the recording of physical conditions. Mr. Richard Brandon recorded physical data in 1967. I would like to thank their supervisors, Dr. John DeWitt and Dr. Richard Ridenhour. I am also grateful to the cooperating agencies and their personnel who were involved with the project.

I would like to express my gratitude to: Dr. John DeWitt for introducing me to the study; Dr. Richard Hurley for his many hours in checking insect identifications; Dr. George Crandell for his continual encouragement and perceptive analytical influence. Lastly, I would like to thank my chairman, Dr. Roger Barnhart, for his many helpful corrections.

ABSTRACT

Because stream fisheries are so closely associated with forested watersheds, it is necessary that the streams and forests be managed jointly under a system of multiple use. This requires a knowledge of the interrelationships between these resources to yield maximum returns from both. It is the purpose of this paper to relate logging practices to fish management by ascertaining the effect of logging-road construction on the drop of insects into a stream.

On the South Fork of Caspar Creek the insects falling into the stream were greatly increased after a logging road was built. A twofold increase in number and weight of insects occurred over the entire stream. In "Disturbed" areas, where the road paralleled the stream, drop insects increased three and one half times by number and one and one half times by weight over the "Insect-Control" area. In the "Highly Disturbed" areas, where the road crossed the stream, insect numbers increased by five and one half times and a threefold increase by weight over the "Insect-Control" area was noted.

A more than proportionate amount of the increase occurred in those adult insects having aquatic immature stages. One such family, Chironomidae, had a greater occurrence after road construction than all insects combined before construction. This family showed the most significant change of the families studied.

INTRODUCTION

Many studies have been conducted on the importance of insects as fish food. The majority of these investigations were analyses of fish stomach contents, a few of which compared the ratios of terrestrial to aquatic insects. Most investigations have shown that terrestrial insects are very important in the diet of stream fish, comprising from 10 to 40 percent of the total diet of some species. It has also been demonstrated that terrestrial insects are most important to the diet of a fish during the summer, with the degree of this importance varying with stream size, and type and density of stream cover.

Demory (1961) and Chapman (1966) found that in small coastal tributaries, similar to Caspar Creek, terrestrial insects made up at least one third of the diet of small coho salmon. Other researchers placed their emphasis on measuring the supply of aquatic insects in a stream by use of Surber and drift samplers. This has proven useful in describing the effect of changing stream conditions, such as sedimentation upon stream insects and has helped relate physical changes to changes in fish production for the lotic environment. However, no work has been done on how the terrestrial derived portion of a fish's diet is affected by changes in the watershed environment, such as logging.

This paper has two basic aims: (1) To determine what insects fall into a stream from an undisturbed and distrubed (after a logging-road has been constructed) redwood type forest. (2) To determine the effect of the disturbance upon the amount of "drop insects" available as fish food at the stream's surface.

STUDY AREA

Location and Description

Caspar Creek, Mendocino County, California is located about 100 miles north of San Francisco, in the heart of the redwood region. The stream originates in Townships 17 and 18 North, Range 17 West, Mount Diablo Meridian, at an approximate elevation of 1,000 feet and drops rapidly to an elevation of 300 feet, then levels off, and slopes gradually for about 6 miles to the Pacific Ocean (Figure 1). Located 5 miles south of Fort Bragg, in the Jackson State Forest, a part of California's Lower Conifer Zone, this typical short coastal stream drains approximately 5,000 acres of second growth trees that are 65 to 80 years old.

One hundred years ago, the whole Caspar Creek watershed and much of the surrounding land was logged to meet the demands of a growing country. The cutover forests were then burned in an effort to make pasture for domestic animals (Raymond, 1964), but despite these efforts, the area is covered today by a vigorous young stand of redwood and Douglas-fir.

The Caspar Creek watershed has two main forks. The north fork drains 1,255 acres and served as a "control area" while the south fork drains 1,050 acres and was the "test area" (Figure 2). The geology, topography, and soil are similar on these twin watersheds, and they are representative of the

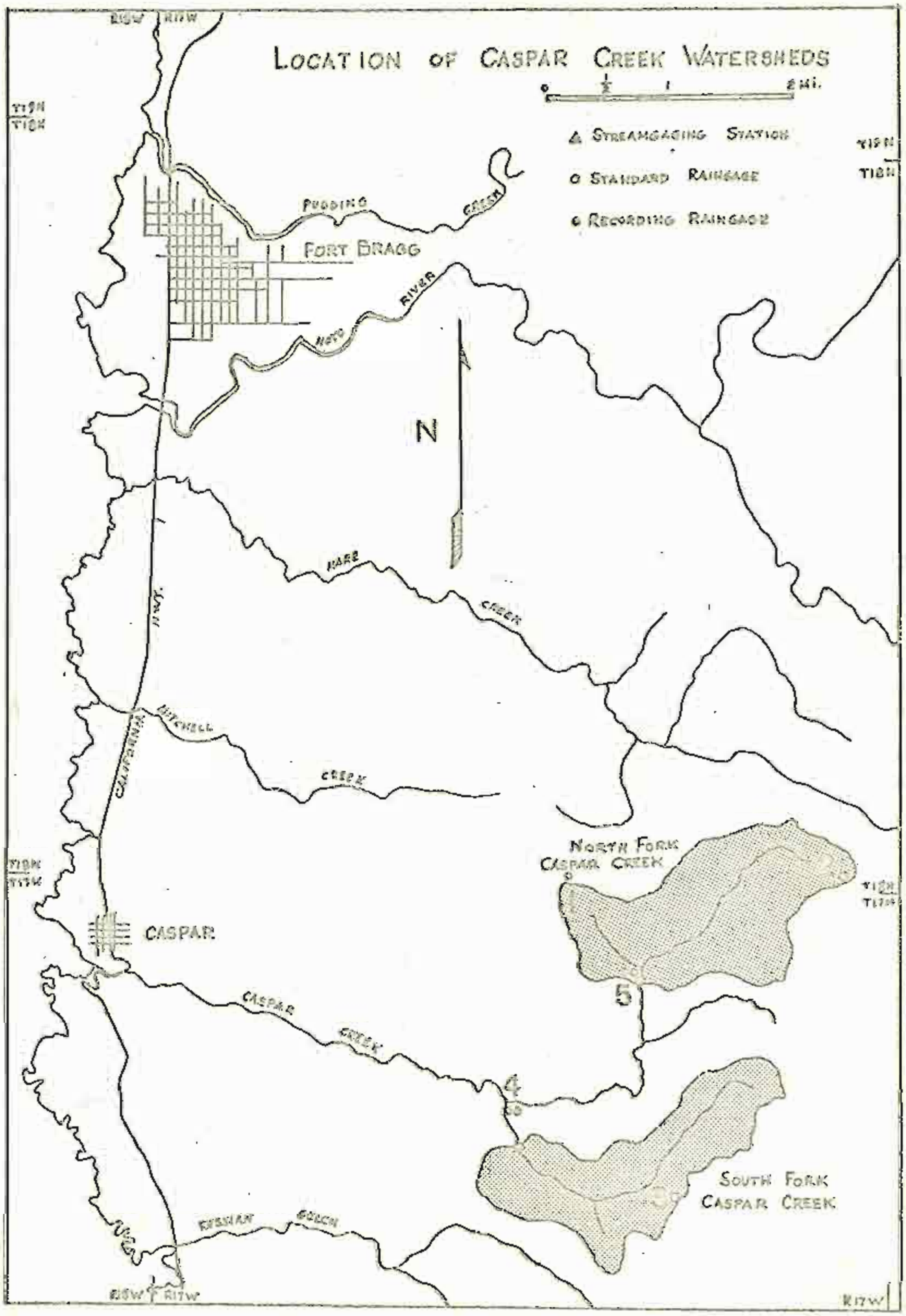

Figure 1. Map of Caspar Creek area.
(S.W.F.& R. Exp. St.)

CASPAR CREEK
MENDOCINO COUNTY

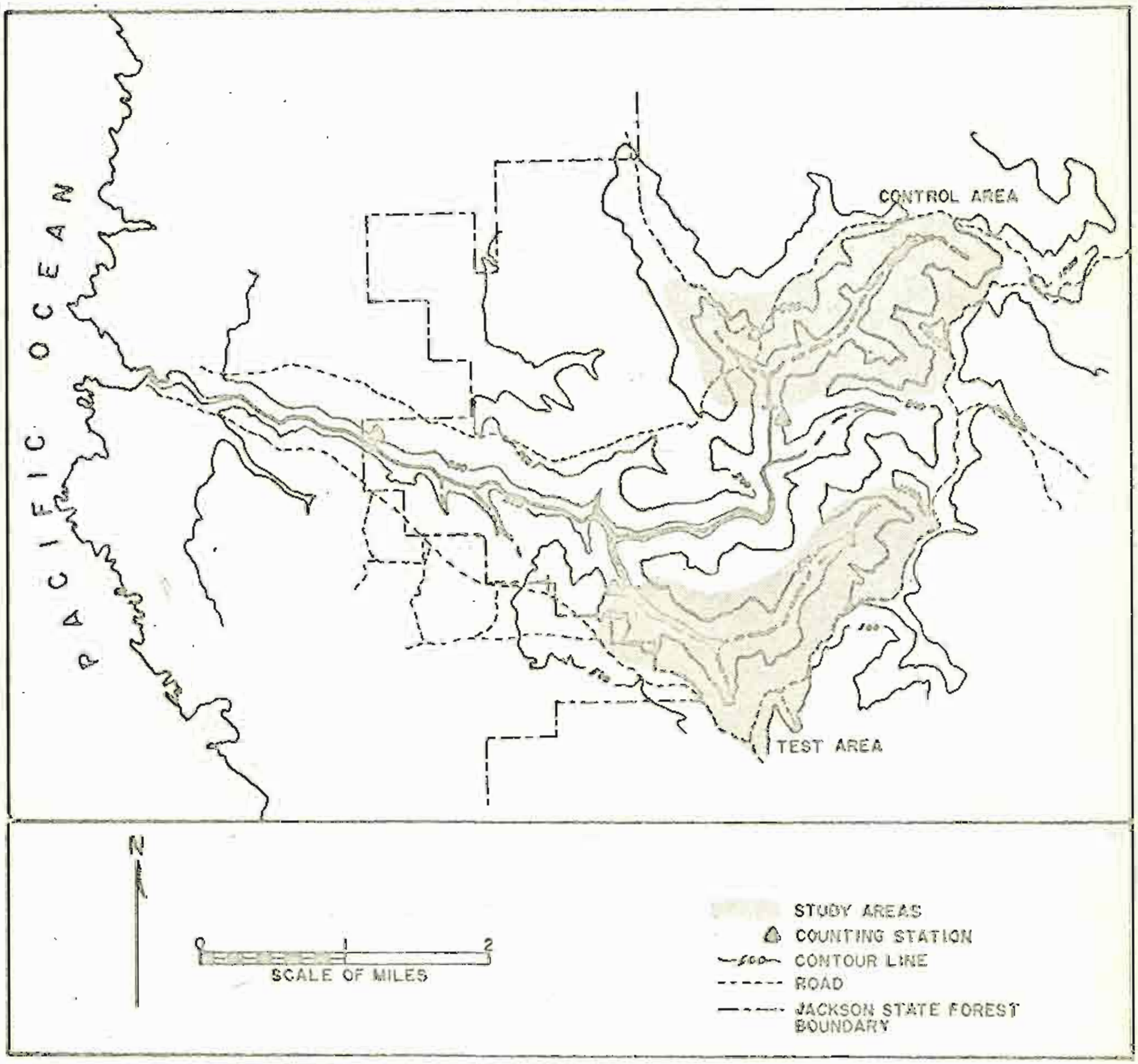

Figure 2. Map of South (Test Area) and North (Control Area) Forks of Caspar Creek.

(Kabel and German, 1967)

timber growing areas in California's redwood region (Raymond, 1964).

Background of the Caspar Creek Project

The Caspar Creek study was initiated in 1961 to determine the effects of logging and its associated activities on a watershed. It is a cooperative project involving the U. S. Forest Service (Pacific Southwest Forest and Range Experiment Station), the California Department of Fish and Game, the California Department of Water Resources, the California Department of Conservation (Division of Forestry), the University of California (School of Forestry) and Humboldt State College.

The project was divided into three segments: First, there was a six year control period during which initial measurements were made; second, a logging road was constructed in the summer of 1967, to be followed by a six year stabilization period; third, the area is to be logged in 1973 and a six year post-logging study made.

To measure the changes occurring in the watershed, special emphasis has been placed on:

1) Stream sediment
2) Stream flow
3) Watershed precipitation
4) Water temperatures
5) Air temperatures
6) Solar radiation
7) Stream canopy

8) Mapping the area

9) Insect drop

with additional information being collected on:

a) Chemical conditions

b) Turbidity

c) Stream drying

d) Algae abundance and distribution

e) Sedimentation areas

f) Pool and riffle ratios

g) Fish distribution and food habits

So that comparisons between north and south forks could be made at specific locations, the entire length of each stream fork was marked with permanent station markers at intervals of one hundred feet, starting at the permanent weirs and going upstream.

Fish Species

Silver salmon (*Oncorhynchus kisutch*) and steelhead rainbow trout (*Salmo gairdnerii*) are the anadromous salmonids that inhabit Caspar Creek. At least one sculpin (*Cottus* sp.), and the three spined stickleback (*Gasterosteus aculeatus*), are common. Some of the trout in the upper part of the creek are probably resident rather than migratory (Kabel and German, 1967).

Stream Flows

Both forks of Caspar Creek become intermittent in the study areas. Flow below their junction is continuous, however, and no bars form in the summer to block the mouth. Highly variable flows are typical of this stream, with low summer flows of 0.11 cfs in the south fork and 0.06 cfs in the north fork recorded at the flow-gaging weirs (P. S. F. and Range Exp. Station, 1963-64 Prog. Rept.) and maximum flows of 288 cfs and 305 cfs in the south and north forks, respectively, recorded in January 1966. Flood flows peak and drop off very rapidly in this drainage (Kabel and German, 1967).

Logging Road and Construction

Road building along the south fork started on May 23, 1967. Generally, clearing and road work progressed downstream from the uppermost part of the study area.

The road-building activity directly affected much of the stream, its bed and banks. Small trees, branches and leaves, and substantial quantities of rock and soil slid into or were deposited in Caspar Creek. At least 361 feet of stream bed were completely altered by bulldozer operations directly in the stream. Almost the entire length of the study area was directly affected in some way by road construction activities. By September 1967, all road construction and stream clearance operations were completed. About 100,000 cubic yards of material were moved during the construction of 3.7 miles of road. The stream clearance program removed much of the coarse organic debris in the stream and along its banks (DeWitt, 1968).

The change in the study area is shown in two aerial photographs supplied by the California Division of Forestry (Gossard, personal communication). The first photo, made in 1959, shows the undisturbed south fork (Figure 3). The second photo, made in 1968, shows the same area after logging road construction (Figure 4).

Post-Construction Procedures

The Caspar Creek logging road construction was planned to be less disruptive to watershed and stream conditions than average operations, but it proved to be more or less typical (DeWitt, 1968). However, after the roads were built, two atypical actions were taken to partly compensate for the disruption caused. First, all coarse debris was removed from the south fork. Second, all banks and exposed slopes along the south fork were fertilized and seeded with rye grass. The grass was well established before the first substantial rains in the fall of 1967.

Effect of Logging Roads

Sediment and Turbidity: Roy Silen, Forester in charge of the H. J. Andrews Experimental Forest, Oregon, stated his observations indicate that the building and use of logging roads constitutes the major source of sediment to logged-over streams (Mustenberg, 1954).

On Caspar Creek the direct felling of trees into the stream and its tributaries increased stream turbidity slightly. For example, when felling was in progress at station 47, and

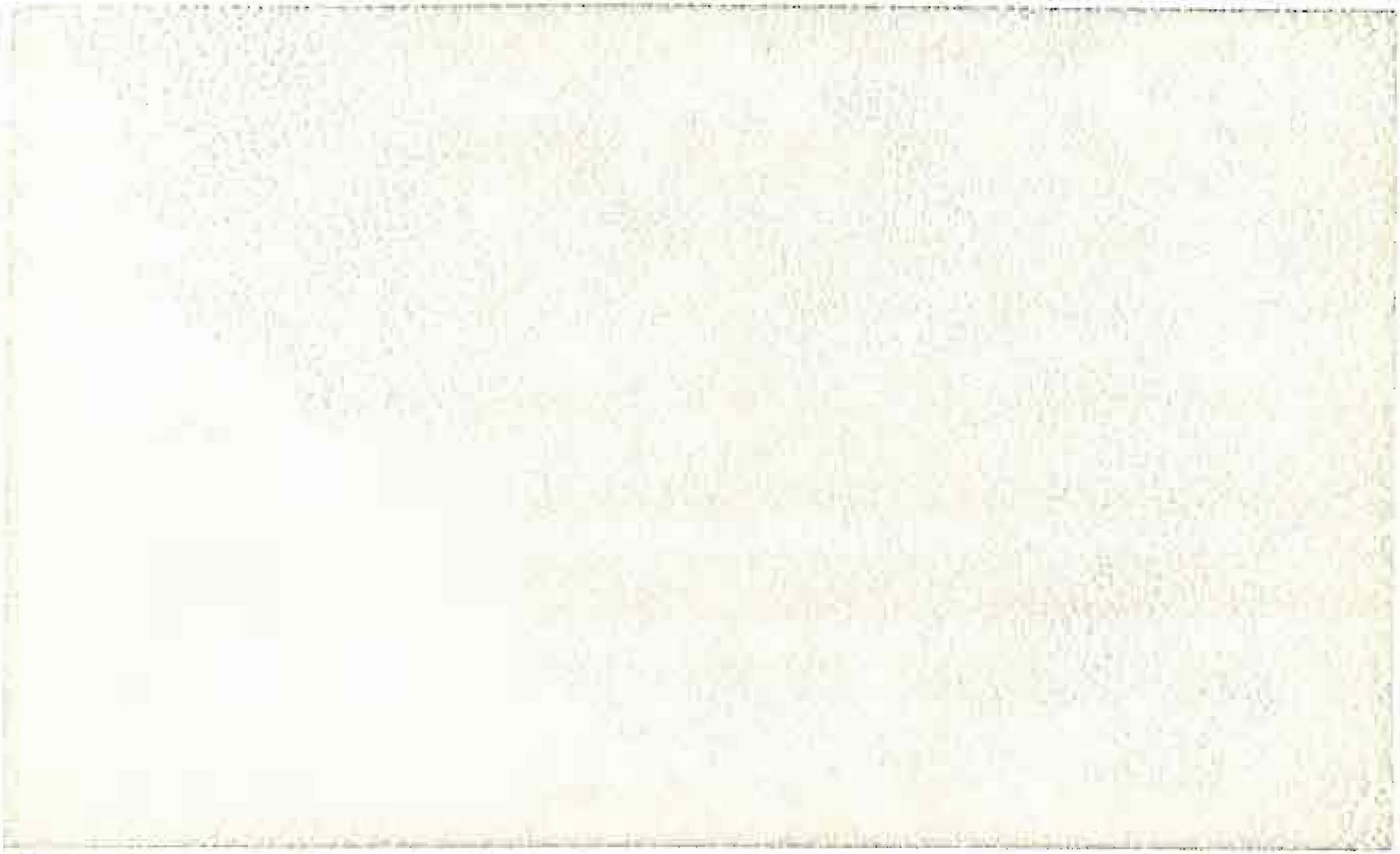

Figure 3. Aerial photograph (1959) of the South Fork of Caspar Creek in undisturbed condition. (CDF)

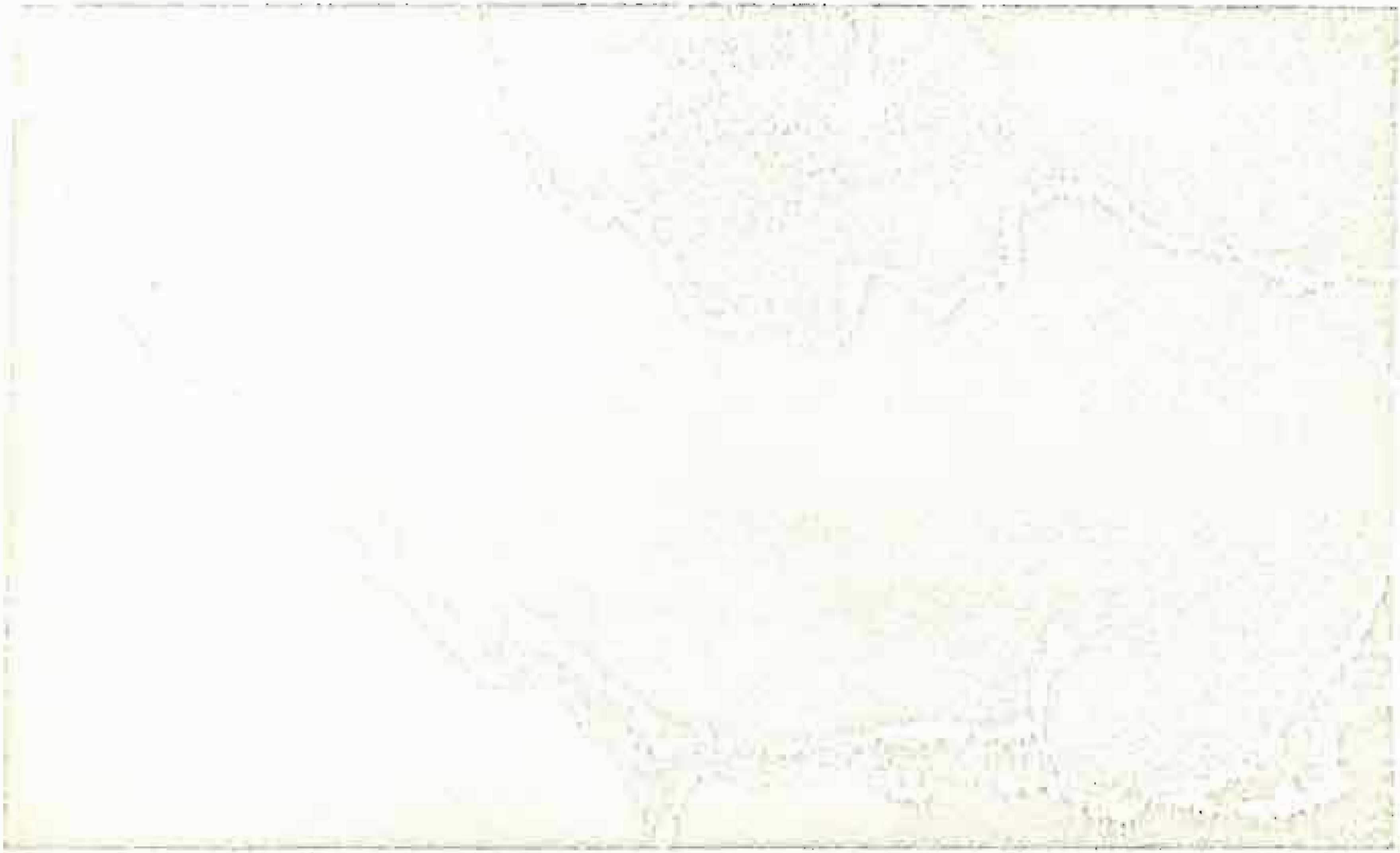

Figure 4. Aerial photograph (1968) of the South Fork of Caspar Creek after a logging road was built in 1967.

(CDF)

on a tributary that entered the south fork at station 44.5, the turbidity was 11 p.p.m. in the south fork below the mouth of the tributary. However, it dropped to 2 p.p.m. about 1000 feet downstream which was approximately the level recorded upstream.

Construction of a stream crossing between stations 67 and 68 on August 12, 1967, resulted in high turbidity for 1000 feet downstream, but no effect was noted on the turbidity at station 4 a mile downstream. The highest turbidity at this station the next day was 18 p.p.m. At station 60 (700 feet downstream), turbidity had returned to around 1 p.p.m., its pre-construction level. Generally, immediate effects of cutting, road building and bridge construction on turbidity were local and of short duration.

After construction the road apparently caused considerable increases in turbidity during periods of heavy rainfall. Winter stream conditions are very important to aquatic insects because of its effect of naiads. On January 14, 1968, during a moderately heavy rainfall, turbidities as high as 3,000 p.p.m. were recorded in the south fork study area as far upstream as station 46. On the same day, north fork turbidity was only 60 p.p.m. (DeWitt, 1968). DeWitt also records some erosion and slippage, resulting in the deposition of as much as two feet of sediment in the stream.

Illumination, Water and Air Temperatures: Illumination, water temperature and air temperature were three physical parameters measured in this project to determine stream environment change. DeWitt (1968) and Dorn (1969) studied the available information for these factors and found a dramatic change after road construction. Because of the importance of these factors in determining insect populations and because of their significant change after road construction, further discussion is warranted.

Illumination at the water surface was determined with a submarine photometer before and after road construction. Spot measurements of illumination were made along the entire length of the study and control streams on clear days between 1100 and 1300 hours PST.

Radiation data for 1965 indicated that the amount of light reaching both forks was about the same before road construction. Maximum photometer readings of around 8,000 microampers were noted at only 2 stations on the north fork (project control) in 1968, while 29 such readings were observed on the south fork where the road was built. This was a fivefold increase in illumination and can be attributed to cover removal (DeWitt, 1968).

South fork summer water temperature also increased after road construction. Before road construction, most summer maximums were 60°F. in both forks. After road building, the south fork frequently experienced maximums approaching 70°F. Most maximums were above 60°F., and some stations showed increases of as much as 20°F. (Dorn, 1969). Dorn was able to correlate all increases in water temperature with cover removal.

Air temperatures also increased after road construction, but the buffering action of the large forested areas still remaining, kept these increases substantially below those observed for water temperature.

For other physical data such as precipitation, stream flow, rate of sediment deposit, etc., I refer the reader to the Pacific Southwest Forest and Experimental Station Progress Reports. DeWitt in his Annual Report for 1968 gives the best available information on changes occurring since road construction.

METHODS AND MATERIALS

Insects dropping to the stream surface of the South Fork of Caspar Creek were collected during the summers of 1966 and 1968. The 1966 collection was from an undisturbed habitat while the 1968 collection was made after a logging road had been constructed through the area the previous year.

Drop Box Insects

"Drop boxes" were used to collect the insects falling into the stream. Each box is 3 feet by 3 feet and is filled with water and appropriate chemicals to capture all insects that come in contact with its surface. This appears to be the first study in which this technique has been used for obtaining quantitative results.

"Drop insect" refers to any insect entering the stream from air or land. Thus, while other investigators have considered adult Plecoptera to be "aquatic insects", this paper will consider them to be "drop insects", since they are reintroduced into the stream from the land.

Field Procedure

The drop-boxes were placed directly in the stream, adjacent to the station marker from which the collections were reported. If there was enough water in the stream to move the drop-boxes, they were placed on rocks to elevate them above the water.

Prior to each collection, the boxes were cleaned completely, and the solutions changed. In 1966 a capful of mineral oil was added to a formalin-water solution to collect insects. In 1968 the formalin was eliminated, since the mineral oil proved adequate for the capture of all insects falling into the drop-box. However, it was found that if the insects remained in the mineral oil samples longer than a single day, they became heavily infested with a fungus (Saprolegnia sp.).

The insects were removed from the drop-box with a small-mesh nylon aquarium net, constructed so that the insects could be skimmed off the collecting solution. The insects were then removed with forceps and put into collecting jars containing a 70 percent solution of ethyl alchohol.

The drop-box collection made prior to road building (1966) was taken opposite station markers 9, 20, 30, 44, 57, 70 and 73. The drop-box collection made after road construction (1968) was not made at particular stations, but was taken randomly along the entire stream.

The length of the collecting period varied with the collector. In 1966, samples generally represented one day of collecting, while in 1968 samples represented one to four days of collecting. A summary of the sampling data is presented in Table 1.

Table 1. A summary of the drop-box sampling procedures for the South Fork of Caspar Creek.

1966 Drop Box Collection--
1) Sampling season: VI/11 - VIII/12/66
2) Number of samples collected: 69
3) Total sampling days: 75
4) Length of sampling periods: 1 to 2 days

1968 Drop Box Collection--
1) Sampling season: VI/24 - VIII/26/68
2) Number of samples collected: 62
3) Total sampling days: 126
4) Length of sampling periods: 1 to 4 days

Laboratory Procedure

All insects in the 1966 and 1968 drop collections were identified to family, using Borror and DeLong (1964). Confirmations were made in Curran (1965), Arnett (1968), and Peterson (1959 and 1960).

Insects which could not be keyed to family because diagnostic parts were missing were keyed to order and put under the heading "unidentifiable". Insect parts that could not be keyed to order were put in a group called "fragments" and were merely weighed.

After identification of all insect families in a single sample, the families were dried for two to four days and weighed. Two to four days was found to be adequate for obtaining constant weights. Weighings were carried out on an analytical balance, to the nearest ten-thousandth of a gram (.0001).

RESULTS

The 1966 insect collection was the result of 75 days sampling; the 1968 collection of 126 days sampling. The total number of keyed insects in the 1966 collection was 2,494, and in the 1968 collection 7,941. The average number of insects collected at one location for one day, known as per sampling day (hereafter referred to as p.s.d.), was 33.3 for 1966, and 63.0 for 1968. Thus the 1968 collection shows a nearly twofold (1.8) p.s.d. increase over the 1966 collection. The average weight of insects p.s.d. for 1966 was 21.2 milligrams; for 1968 it was 35.7 milligrams. This is again a nearly twofold (1.7) increase in weight p.s.d. These results and other important information about the two insect collections are summarized in Table 2.

Order Differences Observed Between 1966 and 1968 Drop Collections

An analysis by order of the numbers and weights of insects collected p.s.d. and their contribution to the total number and weight of insects for the years 1966 and 1968 is given in Table 3. From this table it can be seen that in 1968 all orders except Hymenoptera, Neuroptera and Thysanoptera differed markedly from 1966 in either number or weight (or both) of insects p.s.d.

A brief review of this table shows that Diptera had the greatest and most significant increase (31.5 insects) in

Table 2. A summary by numbers and weights of the 1966 (before road) and 1968 (after road) collections.

1966 Collection (before road)
1) Total number of insects: 2,494
2) Total weight (dry) of insects: 1,587.1 mg
3) Number of immature insects: 155
4) Number of sampling days: 75
5) Average Number of insects per sampling day: 33.25
6) Average Weight of insects per sampling day: 21.16 mg

1968 Collection (after road)
1) Total number of insects: 7,941
2) Total weight (dry) of insects: 4,497.0 mg
3) Number of immature insects: 211
4) Number of sampling days: 126
5) Average Number of insects per sampling day: 63.02
6) Average Weight of insects per sampling day: 35.69 mg

Combined Collections (1966 and 1968)
1) Total number of insects: 10,435
2) Total weight (dry) of insects: 6,084.1 mg

Table 3. Drop box collections for 1966 and 1968 summarized to show the Order contribution by numbers and weights.

(p.s.d.= per sampling day = per square yard)

ORDER	1966 (BEFORE) Number p.s.d.	% Tot	Weight (mg) p.s.d.	% Tot	1968 (AFTER) Number p.s.d.	% Tot	Weight (mg) p.s.d.	% Tot
COLEOPTERA	3.1	9.4%	2.3 mg	10.9%	1.7	2.8%	3.9 mg	11.0%
COLLEMBOLA	.1	.2%	.0 mg	.0%	.3	.5%	.0 mg	.0%
DIPTERA	20.0	60.1%	6.5 mg	30.8%	51.5	81.7%	8.9 mg	25.1%
EPHEMEROPTERA	.5	1.4%	.1 mg	.6%	2.4	3.8%	.8 mg	2.3%
HEMIPTERA	.7	2.2%	.5 mg	2.2%	1.0	1.6%	6.9 mg	19.4%
HOMOPTERA	1.9	5.7%	.7 mg	3.1%	1.1	1.8%	.3 mg	1.0%
HYMENOPTERA	.8	2.5%	.5 mg	2.4%	.5	.8%	.9 mg	2.7%
LEPIDOPTERA	.3	.8%	4.1 mg	19.5%	.2	.4%	1.1 mg	3.2%
NEUROPTERA	.2	.6%	.1 mg	.3%	.1	.2%	.0 mg	.1%
ORTHOPTERA	.2	.5%	2.5 mg	11.7%	.0	.0%	2.0 mg	5.6%
PLECOPTERA	.7	2.1%	.5 mg	2.3%	.2	.3%	.2 mg	.6%

Table 3. (Con'd.)

ORDER	1966 (BEFORE) Number p.s.d.	% Tot	Weight (mg) p.s.d.	% Tot	1968 (AFTER) Number p.s.d.	% Tot	Weight (mg) p.s.d.	% Tot
PSOCOPTERA	2.8	8.5%	.2 mg	1.1%	1.5	2.4%	.1 mg	.2%
THYSANOPTERA	.1	.4%	.0 mg	.0%	.2	.4%	.0 mg	.0%
TRICHOPTERA	.5	1.6%	.2 mg	.8%	1.0	1.6%	9.8 mg	27.[illegible]%
INSECT FRAGMENTS	.1	.2%	.0 mg	.1%	.4	.6%	.2 mg	.5%
NON-INSECT ARACHNID	1.3	3.9%	3.1 mg	14.6%	.8	1.3%	.5 mg	1.3%
***TOTAL	33.3	100.1%	21.2 mg	100.3%	63.0	100.1%	35.7 mg	100.8%

numbers p.s.d. Diptera also constituted 82 percent of the insects keyed in the 1968 drop collection, an increase of 30 percent from 1966. However, Trichoptera showed the most significant change in weight p.s.d. Trichopterans in increasing 9.6 mg. p.s.d. rose from a contribution of less than 1 percent of the weight of 1966 insects to 28 percent of the weight of 1968 insects. This change was significant because the total weight increase of all insects from 1966 to 1968 was only 14.5 mg. p.s.d.

Analysis to Family Level

The combined collections contained 146 different families of insects. Arachnid, Diplopoda, Chilopoda, unidentifiable insects, and insect fragments are also included in the tabulation. A listing of all families identified, their numbers and weight p.s.d., their respective ranks by number and weight, and their percent occurrence** for the 1966 and 1968 collections is given in Table 4.

The 1966 collection contained 109 insect families. Compared to this collection the 1968 contained 114 insect families. Of the insect families, 78 occurred both in 1966 and 1968, and 68 occurred in one year or the other.

** The reader should not compare the 1966 and 1968 collections by percentage occurrence because the length of collecting periods in days was different for each year's samples.

Table 4. Family analysis by number, weight,* and percent occurrence,** for the 1966 and 1968 insect drop-box collections.
(p.s.d.= per sampling day = per square yard)

FAMILY	1966 (BEFORE) Number p.s.d.	Number Rank	Weight p.s.d.	Weight Rank	% Occurr-ence	1968 (AFTER) Number p.s.d.	Number Rank	Weight p.s.d.	Weight Rank	% Occurr-ence
COLEOPTERA	3.1		2.3 mg			1.7		3.9 mg		
Anobiidae	.07	(53)	.051 mg	(53)	4.3%	.01	(98)	.003 mg	(93)	1.6%
Cantharidae	.23	(24)	.151 mg	(25)	14.5%	.08	(43)	.040 mg	(55)	9.7%
Carabidae	–	–	–	–	–	.02	(86)	.006 mg	(84)	3.2%
Cerambycidae	.11	(44)	.048 mg	(54)	8.7%	.02	(86)	.002 mg	(103)	3.2%
Chrysomelidae	.01	(88)	.063 mg	(45)	1.5%	.02	(74)	.098 mg	(33)	3.2%
Cisidae	.01	(80)	.003 mg	(92)	1.5%	–	–	–	–	–
Cleridae	.01	(88)	.072 mg	(40)	1.5%	–	–	–	–	–
Coccinellidae	–	–	–	–	–	.02	(74)	.043 mg	(52)	4.9%
Colydiidae	–	–	–	–	–	.01	(98)	.006 mg	(85)	1.6%
Cryptophagidae	.16	(30)	.037 mg	(57)	7.2%	.02	(86)	.001 mg	(111)	3.2%
Cucujidae	–	–	–	–	–	.01	(98)	.003 mg	(93)	1.6%
Curculionidae	–	–	–	–	–	.02	(74)	.054 mg	(45)	4.8%
Dermestidae	–	–	–	–	–	.01	(98)	.006 mg	(86)	1.6%
Dryopidae	.04	(64)	.053 mg	(51)	2.9%	–	–	–	–	–
Dytiscidae	–	–	–	–	–	.10	(37)	3.267 mg	(3)	9.7%
Elateridae	.09	(46)	.097 mg	(34)	2.9%	–	–	–	–	–
Elmidae	.29	(21)	.140 mg	(29)	14.5%	.21	(29)	.045 mg	(50)	11.3%

*Weighings to .1 mg, the last two figures are from mathematical calculation.

**Percent occurrence (Before and After) should not be compared due to the difference in length of sampling periods before and after road construction.

Table 4. (Con'd.)

FAMILY	1966 (BEFORE) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence	1968 (AFTER) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence
Erotylidae	.01	(88)	.011 mg	(74)	1.5%	-	-	-	-	-
Eucnemidae	.03	(72)	.340 mg	(12)	2.9%	-	-	-	-	-
Euglenidae	-	-	-	-	-	.01	(98)	.000 mg	(119)	1.6%
Gyrinidae	-	-	-	-	-	.01	(98)	.033 mg	(58)	1.6%
Hydrophilidae	.03	(72)	.085 mg	(37)	2.9%	-	-	-	-	-
Lathridiidae	.13	(39)	.011 mg	(74)	10.1%	.04	(59)	.005 mg	(89)	8.1%
Leiodidae	.03	(72)	.016 mg	(68)	2.9%	-	-	-	-	-
Leptodiridae	.07	(53)	.028 mg	(61)	5.8%	.04	(59)	.006 mg	(84)	8.1%
Limnebiidae	.01	(88)	.000 mg	(108)	1.5%	.44	(16)	.026 mg	(65)	22.6%
Lycidae	.01	(88)	.070 mg	(41)	1.5%	-	-	-	-	-
Melandryidae	.01	(88)	.019 mg	(65)	1.5%	-	-	-	-	-
Mordellidae	.03	(72)	.016 mg	(68)	2.9%	.05	(53)	.024 mg	(67)	6.5%
Nitidulidae	.04	(64)	.011 mg	(74)	4.3%	.01	(98)	.000 mg	(119)	1.6%
Orthoperidae	.01	(88)	.000 mg	(108)	1.5%	-	-	-	-	-
Pselaphidae	.01	(88)	.000 mg	(108)	1.5%	-	-	-	-	-
Psephenidae	.01	(88)	.004 mg	(87)	1.5%	-	-	-	-	-
Ptiliidae	.12	(41)	.001 mg	(97)	5.8%	-	-	-	-	-
Rhizophagidae	.01	(88)	.001 mg	(97)	1.5%	-	-	-	-	-
Scarabaeidae	.04	(64)	.378 mg	(10)	2.9%	-	-	-	-	-
Scolytidae	.03	(72)	.043 mg	(56)	2.9%	.15	(33)	.145 mg	(26)	19.4%
Silphidae	.03	(72)	.017 mg	(67)	2.9%	-	-	-	-	-
Staphylinidae	1.39	(7)	.354 mg	(11)	42.0%	.38	(19)	.060 mg	(41)	38.7%
Tenebrionidae	.01	(88)	.176 mg	(22)	1.5%	-	-	-	-	-
Throscidae	.03	(72)	.016 mg	(68)	2.9%	.04	(59)	.027 mg	(64)	8.1%

Table 4. (Con'd.)

FAMILY	1966 (BEFORE) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence	1968 (AFTER) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence
Unidentifiable Col.	-	-	-	-	-	.04	(59)	.003 mg	(93)	8.1%
COLLEMBOLA	.1		.0 mg			.3		.0 mg		
Entomobryidae	.07	(53)	.000 mg	(108)	7.2%	.27	(27)	.002 mg	(99)	33.9%
Poduridae	.01	(88)	.000 mg	(108)	1.5%	-	-	-	-	-
Sminthuridae	-	-	-	-	-	.02	(86)	.000 mg	(119)	1.6%
DIPTERA	20.0		6.5			51.5		8.9		
Agromyzidae	.01	(88)	.005 mg	(84)	1.5%	-	-	-	-	-
Anthomyiidae	.08	(50)	.201 mg	(19)	7.2%	.02	(86)	.070 mg	(37)	3.2%
Asilidae	.03	(72)	.137 mg	(30)	2.9%	.05	(53)	.306 mg	(17)	6.5%
Bibionidae	.17	(26)	.168 mg	(23)	10.1%	.02	(86)	.013 mg	(75)	3.2%
Bombyliidae	-	-	-	-	-	.01	(98)	.005 mg	(89)	1.6%
Conopidae	.01	(88)	.004 mg	(87)	1.5%	-	-	-	-	-
Cecidomyiidae	3.99	(2)	.036 mg	(58)	69.6%	2.87	(2)	.052 mg	(46)	79.0%
Ceratopogonidae	.15	(33)	.019 mg	(65)	15.9%	.72	(11)	.047 mg	(48)	58.1%
Chamaemyiidae	-	-	-	-	-	.05	(53)	.002 mg	(103)	9.7%
Chironomidae	2.17	(4)	.055 mg	(49)	79.7%	34.53	(1)	2.127 mg	(4)	98.4%
Chloropidae	.04	(64)	.005 mg	(84)	1.5%	-	-	-	-	-
Coelopidae	.12	(41)	.053 mg	(51)	8.7%	.04	(59)	.010 mg	(79)	8.1%
Culicidae	-	-	-	-	-	.03	(69)	.011 mg	(77)	6.5%
Dixidae	-	-	-	-	-	.14	(35)	.043 mg	(52)	22.6%
Dolichopodidae	1.37	(8)	1.991 mg	(8)	24.6%	.68	(12)	.176 mg	(20)	58.1%
Empididae	1.72	(5)	.405 mg	(9)	58.0%	2.50	(4)	.923 mg	(7)	91.9%

Table 4. (Con'd.)

FAMILY	1966 (BEFORE) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence	1968 (AFTER) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence
Ephydridae	4.31	(1)	.999 mg	(6)	65.2%	2.60	(3)	.840 mg	(8)	80.6%
Muscidae	1.17	(10)	1.005 mg	(5)	50.7%	.28	(26)	.719 mg	(11)	37.1%
Mycetophilidae	.60	(14)	.105 mg	(20)	39.1%	.44	(17)	.174 mg	(21)	53.2%
Phoridae	.60	(14)	.069 mg	(43)	31.9%	.46	(15)	.033 mg	(50)	43.5%
Pipunculidae	.05	(57)	.025 mg	(63)	5.8%	.01	(98)	.002 mg	(103)	1.6%
Psychodidae	.27	(22)	.005 mg	(84)	24.6%	.02	(74)	.001 mg	(111)	4.8%
Rhagionidae	.17	(26)	.152 mg	(24)	15.9%	.25	(28)	.577 mg	(12)	27.4%
Sarcophagidae	—	—	—	—	—	.02	(74)	.133 mg	(27)	4.8%
Scatopsidae	.03	(72)	.012 mg	(72)	2.9%	.01	(98)	.002 mg	(99)	1.6%
Sciaridae	1.72	(5)	.077 mg	(38)	76.8%	2.07	(6)	.153 mg	(23)	80.6%
Simuliidae	.16	(30)	.003 mg	(92)	11.6%	.42	(18)	.017 mg	(71)	45.2%
Sphaeroceridae	.08	(50)	.012 mg	(72)	8.7%	.17	(31)	.039 mg	(56)	24.2%
Stratiomyidae	—	—	—	—	—	.03	(69)	.124 mg	(29)	4.8%
Syrphidae	.04	(64)	.150 mg	(25)	4.3%	.01	(98)	.017 mg	(69)	1.6%
Tachinidae	.11	(44)	.297 mg	(13)	5.8%	.06	(51)	.420 mg	(14)	11.3%
Tipulidae	.79	(11)	.440 mg	(8)	49.3%	2.50	(4)	1.791 mg	(6)	85.5%
Trichoceridae	.01	(88)	.004 mg	(87)	1.5%	—	—	—	—	—
Unidentifiable Dip.	.03	(72)	.001 mg	(97)	4.3%	.37	(20)	.042 mg	(54)	33.9%
EPHEMEROPTERA	.5		.1 mg			2.4		.8 mg		
Baetidae	.37	(19)	.060 mg	(47)	27.5%	1.17	(8)	.235 mg	(18)	72.6%
Ephemeridae	—	—	—	—	—	.06	(46)	.057 mg	(43)	9.7%
Heptageniidae	.08	(50)	.067 mg	(44)	7.2%	.37	(20)	.376 mg	(15)	30.6%
Unidentifiable Eph.	—	—	—	—	—	.76	(10)	.160 mg	(22)	62.9%

Table 4. (Con'd.)

FAMILY	1966 (BEFORE) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence	1968 (AFTER) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence
HEMIPTERA	.7		.5 mg			1.0		6.9 mg		
Anthocoridae	.03	(72)	.033 mg	(59)	2.9%	–	–	–	–	–
Aradidae	.07	(56)	.063 mg	(45)	7.2%	–	–	–	–	–
Colantocoridae	–	–	–	–	–	.01	(98)	.002 mg	(103)	1.6%
Coreidae	.03	(72)	.241 mg	(17)	2.9%	.34	(23)	6.387 mg	(2)	37.1%
Lygaeidae	.05	(57)	.020 mg	(64)	5.8%	.01	(98)	.009 mg	(80)	1.6%
Miridae	.39	(18)	.096 mg	(35)	36.2%	.15	(33)	.099 mg	(32)	24.2%
Pentatomidae	.01	(88)	.001 mg	(97)	1.5%	.02	(86)	.004 mg	(91)	3.2%
Saldidae	.01	(88)	.008 mg	(81)	1.5%	.34	(23)	.331 mg	(16)	27.4%
Veliidae	–	–	–	–	–	.06	(46)	.011 mg	(77)	11.3%
Unidentifiable Hem.	.15	(33)	.001 mg	(97)	14.5%	.10	(41)	.016 mg	(73)	16.1%
HOMOPTERA	1.9		.7 mg			1.1		.3 mg		
Achilidae	–	–	–	–	–	.01	(98)	.033 mg	(60)	1.6%
Aphididae	.63	(13)	.032 mg	(60)	43.5%	.54	(14)	.017 mg	(69)	59.7%
Cicadellidae	.71	(12)	.123 mg	(31)	49.3%	.34	(23)	.117 mg	(30)	46.8%
Cixiidae	.05	(57)	.143 mg	(27)	4.3%	.05	(53)	.146 mg	(25)	9.7%
Delphacidae	–	–	–	–	–	.10	(37)	.032 mg	(61)	16.1%
Margarodidae	–	–	–	–	–	.01	(98)	.000 mg	(119)	1.6%
Membracidae	.01	(88)	.073 mg	(39)	1.5%	–	–	–	–	–
Phylloxeridae	–	–	–	–	–	.04	(59)	.000 mg	(119)	8.1%
Psyllidae	.45	(17)	.279 mg	(14)	27.5%	–	–	–	–	–
Unidentifiable Hom.	.04	(64)	.000 mg	(108)	4.3%	.02	(74)	.000 mg	(119)	3.2%

Table 4. (Con'd.)

FAMILY	1966 (BEFORE) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence	1968 (AFTER) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence
HYMENOPTERA	.8		.5 mg			.5		.9 mg		
Apidae	.01	(88)	.256 mg	(16)	1.5%	–	–	–	–	–
Braconidae	.09	(46)	.009 mg	(78)	10.1%	.06	(46)	.028 mg	(63)	12.9%
Ceraphronidae	.01	(88)	.001 mg	(97)	1.5%	–	–	–	–	–
Cynipidae	.03	(72)	.009 mg	(78)	2.9%	.01	(98)	.002 mg	(103)	1.6%
Diapriidae	.03	(72)	.003 mg	(92)	2.9%	–	–	–	–	–
Dryinidae	.01	(88)	.001 mg	(97)	1.5%	.02	(86)	.001 mg	(111)	3.2%
Elasmidae	.01	(88)	.000 mg	(108)	1.5%	–	–	–	–	–
Encyrtidae	.13	(38)	.007 mg	(82)	13.0%	.05	(53)	.002 mg	(103)	9.7%
Eulophidae	.04	(64)	.001 mg	(97)	4.3%	.04	(59)	.000 mg	(119)	8.1%
Eurytomidae	–	–	–	–	–	.04	(59)	.003 mg	(93)	4.8%
Formicidae	.12	(41)	.111 mg	(32)	7.2%	.07	(44)	.093 mg	(34)	11.3%
Ichneumonidae	.19	(25)	.071 mg	(41)	15.9%	.11	(36)	.062 mg	(40)	19.4%
Mymaridae	.01	(88)	.000 mg	(108)	1.5%	.02	(74)	.002 mg	(99)	4.8%
Proctotrupidae	.01	(88)	.003 mg	(92)	1.5%	.01	(98)	.002 mg	(103)	1.6%
Pteromalidae	.05	(57)	.003 mg	(92)	5.8%	.07	(44)	.006 mg	(86)	12.9%
Torymidae	.05	(57)	.001 mg	(97)	5.8%	.01	(98)	.001 mg	(111)	1.6%
Vespidae	–	–	–	–	–	.02	(74)	.737 mg	(10)	4.8%
Unidentifiable Hym.	.03	(72)	.000 mg	(108)	2.9%	–	–	–	–	–
LEPIDOPTERA	.3		4.2 mg			.2		1.1 mg		
Arctiidae	–	–	–	–	–	.02	(74)	.031 mg	(62)	4.8%
Citheroniidae	–	–	–	–	–	.01	(98)	.125 mg	(28)	1.6%
Geometridae	.09	(46)	.543 mg	(7)	8.7%	.06	(51)	.075 mg	(35)	8.1%
Glyphipterygidae	–	–	–	–	–	.01	(98)	.003 mg	(93)	1.6%

Table 4. (Con'd.)

FAMILY	1966 (BEFORE) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence	1968 (AFTER) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurr-ence
Gracilariidae	.01	(88)	.027 mg	(62)	1.5%	.03	(69)	.017 mg	(71)	6.5%
Noctuidae	.05	(57)	3.293 mg	(1)	5.8%	.02	(86)	.772 mg	(9)	3.2%
Oecophoridae	–	–	–	–	–	.01	(98)	.001 mg	(111)	1.6%
Pyralidae	.09	(46)	.259 mg	(15)	10.1%	.04	(59)	.069 mg	(38)	8.1%
Pyromorphidae	–	–	–	–	–	.01	(98)	.013 mg	(75)	1.6%
Thyrididae	–	–	–	–	–	.01	(98)	.000 mg	(119)	1.6%
Tortricidae	.01	(88)	.004 mg	(87)	1.5%	.01	(98)	.007 mg	(82)	1.6%
Unidentifiable Lep.	–	–	–	–	–	.02	(74)	.007 mg	(82)	4.8%
NEUROPTERA	.2		.1 mg			.1		.0 mg		
Coniopterygidae	.04	(64)	.004 mg	(87)	4.3%	.02	(86)	.002 mg	(99)	3.2%
Hemerobiidae	.15	(33)	.055 mg	(49)	13.0%	.10	(41)	.044 mg	(51)	14.5%
ORTHOPTERA	.2		2.5 mg			.0		2.0 mg		
Gryllacrididae	.16	(30)	2.471 mg	(3)	15.9%	.02	(86)	1.980 mg	(5)	3.2%
PLECOPTERA	.7		.5 mg			.2		.2 mg		
Chloroperlidae	.52	(16)	.212 mg	(18)	33.3%	.10	(37)	.056 mg	(44)	11.3%
Nemouridae	.15	(33)	.088 mg	(36)	11.6%	.05	(53)	.063 mg	(39)	4.8%
Perlidae	.01	(88)	.181 mg	(21)	1.5%	–	–	–	–	–
Perlodidae	–	–	–	–	–	.01	(98)	.102 mg	(31)	1.6%
Unidentifiable Plc.	–	–	–	–	–	.01	(98)	.002 mg	(103)	1.6%

Table 4. (Con'd.)

FAMILY	1966 (BEFORE) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurrence	1968 (AFTER) Number p.s.d.	Rank	Weight p.s.d.	Rank	% Occurrence
PSOCOPTERA	2.8		.2 mg			1.5		.1 mg		
Mesopsocidae	.17	(26)	.011 mg	(74)	15.9%	.03	(69)	.004 mg	(91)	6.5%
Polypsocidae	.24	(23)	.060 mg	(47)	17.4%	.04	(59)	.003 mg	(93)	8.1%
Pseudocaecilidae	2.40	(3)	.107 mg	(33)	76.8%	1.35	(7)	.060 mg	(41)	80.6%
Psocidae	.17	(26)	.045 mg	(55)	14.5%	.10	(37)	.013 mg	(74)	19.4%
Unidentifiable Pso.	.01	(88)	.000 mg	(108)	1.5%	–	–	–	–	–
THYSANOPTERA	.1		.0 mg			.2		.0 mg		
Phloeothripidae	–	–	–	–	–	.06	(46)	.001 mg	(111)	8.1%
Thripidae	.13	(38)	.001 mg	(97)	13.0%	.17	(32)	.001 mg	(111)	22.6%
TRICHOPTERA	.5		.2 mg			1.0		9.8 mg		
Brachycentridae	.03	(72)	.007 mg	(82)	2.9%	.01	(98)	.009 mg	(80)	1.6%
Calamoceratidae	–	–	–	–	–	.03	(69)	.196 mg	(19)	6.5%
Hydroptilidae	.35	(20)	.016 mg	(68)	21.7%	.63	(13)	.046 mg	(49)	53.2%
Lepidostomatidae	.15	(33)	.141 mg	(28)	13.0%	.06	(46)	.036 mg	(57)	8.1%
Limnephilidae	–	–	–	–	–	.18	(30)	9.402 mg	(1)	27.4%
Phryganeidae	–	–	–	–	–	.02	(86)	.051 mg	(47)	3.2%
Rhyacophilidae	–	–	–	–	–	.02	(74)	.075 mg	(36)	4.8%
Unidentifiable Tri.	–	–	–	–	–	.02	(74)	.018 mg	(68)	4.8%
INSECT FRAGMENTS	.05	(57)	.009 mg	(78)	7.2%	.36	(22)	.149 mg	(24)	77.4%

Table 4. (Con'd.)

	1966 (BEFORE)					1968 (AFTER)				
	Number		Weight		% Occurr-ence	Number		Weight		% Occurr-ence
	p.s.d.	Rank	p.s.d.	Rank		p.s.d.	Rank	p.s.d.	Rank	
NON-INSECT										
ARACHNID	1.28	(9)	3.079 mg	(2)	63.8%	.84	(9)	.475 mg	(13)	74.2%
CHILOPODA	.01	(88)	.001 mg	(97)	1.5%	.01	(98)	.001 mg	(111)	1.6%
DIPLOPODA	–	–	–	–	–	.01	(98)	.026 mg	(65)	1.6%
**TOTAL	33.3		21.2 mg			63.0		35.7 mg		

A brief analysis of the main "family" changes as reflected by the two collections follows. It deals principally with those families constituting a substantial part of the collections by either weight or numbers.

The Coleoptera (beeltes), in general, can be characterized as having a large number of families represented, each of which occurred a few times; the families collected changed markedly from 1966 to 1968. The most important changes are: (1) "Dytiscidae" did not occur in 1966 but were thirty-seventh numerically and third on the weight listing of the insects collected in 1968. They constituted over 80% of the weight of Coleopterans in 1968. (2) "Limnebiidae" increased more than forty fold in number and weight from 1966 to 1968, but because they are very small, this large increase resulted in only a small addition to the total weight. (3) "Staphylinidae" showed a decline in importance from a rank of seventh by number and eleventh by weight to nineteenth and forty-first respectively.

The only family of Collembola appearing consistently in the samples was "Entomobryidae". It showed over a fourfold increase by number and weight from 1966 to 1968.

The greatest number of changes occurred in the large order, Diptera. In both years Dipterans constituted more than 60% of the insects by number and more than 25% of their weight. Of the important changes occurring in this order from 1966 to 1968, the principal increases by number and weight were found in the families "Ceratopogonidae", "Chironomidae", "Empididae", and "Tipulidae". Chironomids were fourth in abundance and forty-ninth in importance by weight classification in 1966. They increased fifteen fold to become the most abundant family and fourth most important by weight in 1968. In 1968 this family occurred at the rate of 34.5 insects p.s.d., accounting for over half of that year's total number of insects; it was more abundant than all families combined (33.3 insects p.s.d.) for 1966. The tipulids (crane flies) also showed a significant change, from a number rank of eleventh to fourth. The families Empididae and Ceratopogonidae showed less striking but still highly significant changes.

Decreases in abundance also occurred in this order, notably in the families "Cecidomyiidae", "Dolichopodidae", "Ephydridae" and "Muscidae". The greatest decline was seen in the ephydrids, the most abundant family in 1966 when they occurred at 4.3 insects p.s.d. They dropped to third rank in 1968, occurring at ony 2.7 insects p.s.d. Cecidomyiids, dolichopodids, and muscids all decreased by about one insect p.s.d.

All families of Ephemeroptera (mayflies) increased in abundance from 1966 to 1968. The baetids are the most noteworthy because they increased by almost a full insect per sampling day, and showed a change from nineteenth to eighth in numerical rank.

The increased importance of the order Hemiptera, after the road was constructed, can be attributed to increases in two semi-aquatic families, "Gerridae" and "Saldidae". The gerrids (water-striders) increased over tenfold in number to become the twenty-third most abundant family. They also became second in importance by weight analysis. Salidae (shore-bugs) increased to twenty-five times their former numbers and were twenty-third in family abundance. Miridae (leaf-hoppers) which were the most abundant hemipteran family in 1966, decreased to only one-half their previous abundance in 1968. They were replaced as the most abundant hemipteran by Gerridae and Saldidae.

Many families in the order Homoptera show decreases in numbers and weight while a few families show increases, these increases being very small. The most striking declines are displayed by the families "Cicadellidae" and "Psyllidae". Psyllids were seventeenth in abundance and ranked fourteenth by weight in 1966, but no members of this family appeared in the 1968 collections.

The order Hymenoptera showed insignificant change after road construction.

There are only two notable changes occurring in the Lepidoptera (moths). Both the "Noctuidae" and "Pyralidae" decreased. Noctuidae are especially notable since they experienced a fourfold decrease in weight, sinking from first rank in 1966 to ninth rank in 1968.

Only two families of Neuroptera were present in the collections. Both showed decreases in abundance in 1968, but because their presence was of minor importance originally, these decreases are not significant.

Gryllacrididae, the only family of Orthoptera present, showed a marked, tenfold, decrease in abundance.

The order Plecoptera showed a general decrease in abundance. The two most prevalent families "Chloroperlidae" and "Nemouridae" had numerical decreases of fivefold and threefold respectively.

All families of Psocoptera decreased in abundance, the decline ranging from two to six-fold. The Pseudocaeciliidae, which was the third most abundant family in 1966, with 2.4 insects occurring p.s.d., dropped to seventh in abundance in 1968 with a rate of occurrence of 1.3 insects per day.

The order Thysanoptera showed very little change before and after road construction.

The Trichoptera (caddis-flies) tended to increase in abundance after road construction. The greatest change occurred in the family "Limnephilidae". This family was not present in the 1966 drop collection but was the largest contributor by weight to the 1968 collection.

Arachnids dropped from second in weight contributions in the 1966 drop collection to thirteenth in the 1968 collection.

The number of unidentifiable insects increased considerably in the 1968 collection due to a white fungus (Saprolegnia sp.), which attacked many preserved specimens.

A brief summary of the three most important numerically occurring insect families in each collection shows interesting changes. In 1966, Ephydridae (1), Cecidomyiidae (2), and Pseudocaeciliidae (3) were most numerous. In contrast, Chironomidae (1), Cecidomyiidae (2), and Ephydridae (3) were most important numerically in 1968. A summary by weight for 1966 shows, Noctuidae (1), Arachnids (2), and Gryllacrididae (3) most important while 1968 figures show, Limnephilidae (1), Gerridae (2), and Dytiscidae (3) as the outstanding weight contributors.

When the 1966 and 1968 collections are compared with regards to those families constituting over 2% of a year's collection, an interesting result is observed. Thirteen families had over 2% occurrence by number in 1966 while only seven families had this occurrence in 1968. This result tends to indicate that the 1968 disturbance due to road construction caused large increases in a few families but that the vast majority of families were less well represented. All but one of the families in the 1968 collection appearing at a 2% or greater occurrence were in the order Diptera, the order which showed the largest increase in numbers of insects.

ANALYSIS AND DISCUSSION

Comparison of 1966 and 1968 Collections for Variations Due to Presence of a Logging Road

Initially the North Fork of Caspar Creek was to serve as a control for comparison of insect collections between 1966 and 1968. However, no insect collection was made in 1968 on the north fork. Another problem encountered in analysis was that insect collections were not made at the same station on similar dates between years, thus eliminating the possibility of comparing collections on a station by station basis. However, comparison between years is possible through "total" stream data, and those parts into which it may be subdivided. To serve as a control, stations 3 - 9 on the south fork were designated as an "Insect-Control" area because this area was not directly affected by logging-road construction.

The remaining stations on the south fork were divided into categories based on the amount of disturbance caused by logging-road construction. The two categories showing the most disturbance, "Disturbed" and "Highly Disturbed", were then compared to the 1966 and 1968 "Insect-Control" areas.

The "Insect-Control" is an area where neither the road nor any disturbing activity associated with it, comes closer than 300 feet to the stream (Figure 4). The "Disturbed" areas are stations where most of the vegetation has been removed in at least a 100 foot radius of the stream. "Highly Disturbed" areas are bridge locations (Figure 4 and 5) and are characterized by complete removal of all vegetation in at least a 300 foot radius of the bridge.

The 1966 "Insect-Control" area was compared to the 1968 "Insect-Control" area. The data in Figure 6 and Table 5 indicate an approximate one-quarter decrease in number (30%) and weights (20%) of insects p.s.d. in 1968. The "Insect-Control" area information thus indicates a decrease of insects due to annual fluctuation while the entire study area had a twofold increase.

"Disturbed" and "Highly Disturbed" areas had large increases in weights and numbers over the "Insect Control" area. The "Disturbed" areas exhibited almost a fourfold (3.7) increase in numbers p.s.d. over the "Insect-Control" area and an increase of 1.6 times by weight. The "Highly Disturbed" areas had over a fivefold (5.5) increase in numbers p.s.d. when compared with the 1968 control area, and a threefold (3.2) increase by weight.

Table 5 shows that the order most responsible for the change in numbers was Diptera while Diptera, Hemiptera and Trichoptera were all important in the weight increase.

Tests were also performed on these categories to find the likelihood of their being similar and to evaluate bias introduced by differing sampling times. An analysis for comparability of the areas was made by a Wilcoxon's two sample test, modified for unequal-sized samples by Mann and Whitney (Steel and Torrie, 1960). The "Insect-Controls",

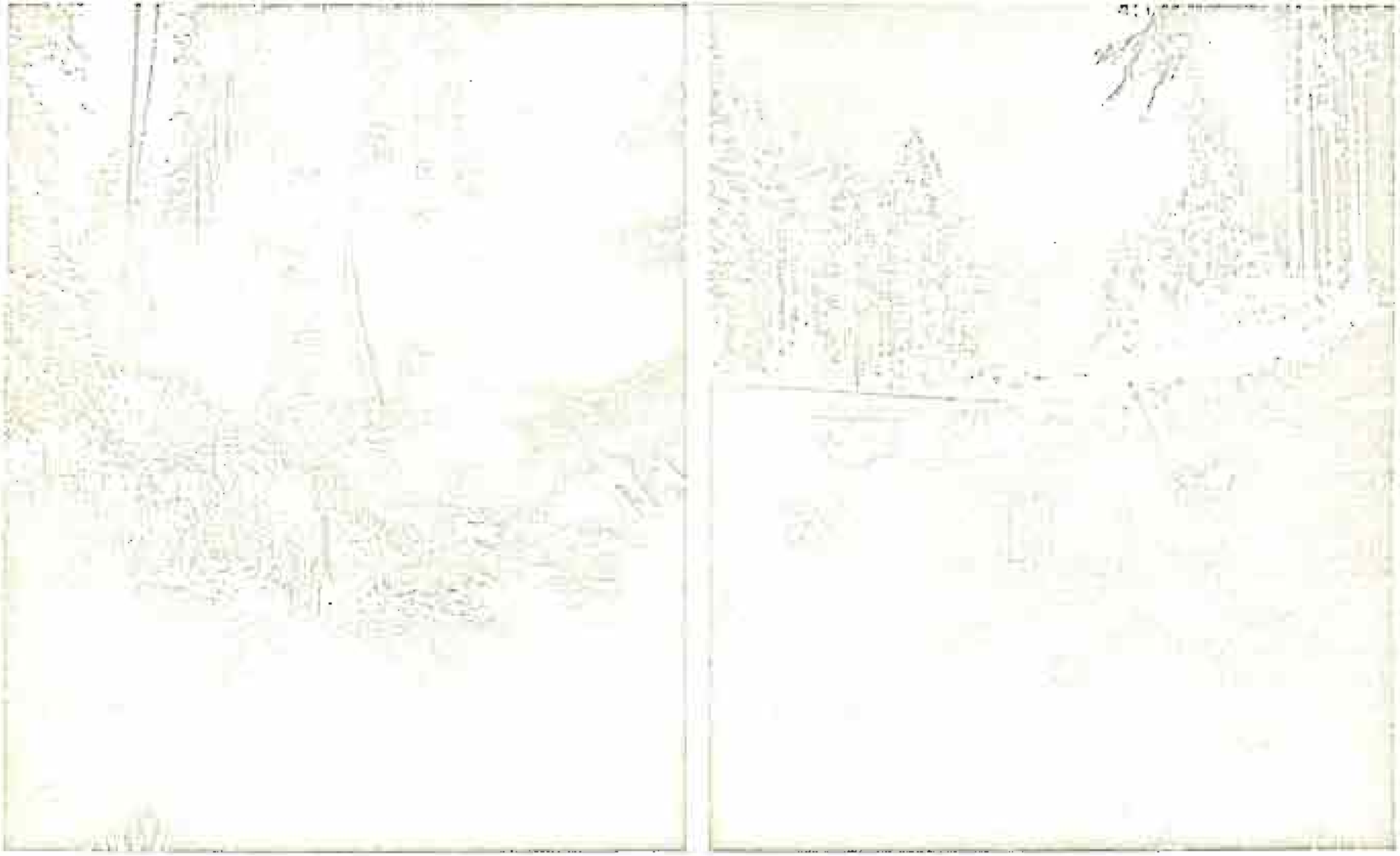

Figure 5. Photos before and after construction of a bridge crossing above Station #44. This is classified as a "Highly Disturbed" area.
(DeWitt, personal communication)

1966 INSECT-CONTROL (Before Road)
a) No. of sampling stations: 1
b) No. of days sampled: 11

1968 INSECT-CONTROL (After Road, unaffected by road)
a) No. of sampling stations: 7
b) No. of days sampled: 16

1968 DISTURBED
a) No. of sampling stations: 11
b) No. of days sampled: 22

1968 HIGHLY DISTURBED (Bridge crossings of stream)
a) No. of sampling stations: 2
b) No. of days sampled: 4

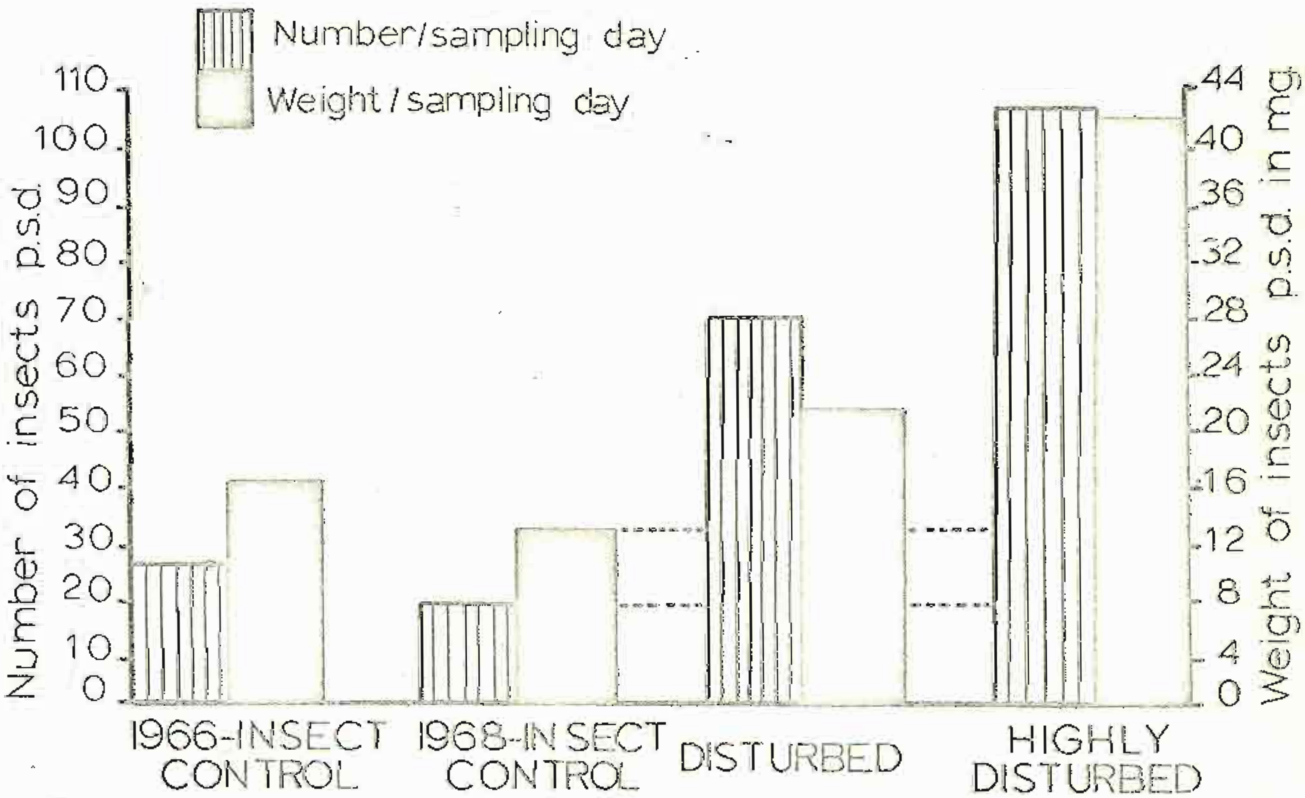

Figure 6. Diagram showing a decrease in numbers and weights of insects per sampling day in Insect-Control area (1966 to 1968), but an increase in the Disturbed areas after the logging-road was built.

Table 5. An Order summary of the 1966 Insect-Control area, 1968 Insect-Control area, Disturbed area, and Highly Disturbed area.

All numbers and weights are expressed as p.s.d.-per sampling day this is equivalent to drop per square yard of stream surface

ORDER	1966 INSECT-CONTROL		1968 INSECT-CONTROL		DISTURBED		HIGHLY DISTURBED	
	Number	Weight mg	Number	Weight mg	Number	Weight mg	Number	Weight mg
COLEOPTERA	2.1	3.7 mg	.0	.0 mg	1.1	.8 mg	1.0	.6 mg
COLLEMBOLA	.1	.0 mg	.0	.0 mg	.2	.0 mg	.2	.0 mg
DIPTERA	17.8	4.5 mg	16.5	4.9 mg	60.8	10.1 mg	97.8	8.2 mg
EPHEMEROPTERA	.3	.0 mg	.4	.1 mg	2.0	.9 mg	1.0	.1 mg
HEMIPTERA	.9	.2 mg	.2	.0 mg	1.2	4.1 mg	.8	4.8 mg
HOMOPTERA	1.4	.3 mg	.3	.3 mg	1.3	.1 mg	.8	.1 mg
HYMENOPTERA	.6	.1 mg	.2	2.8 mg	.4	.2 mg	.0	.0 mg
LEPIDOPTERA	.1	.2 mg	.1	.0 mg	.5	.8 mg	.8	.3 mg
NEUROPTERA	.1	.0 mg	.0	.0 mg	.1	.1 mg	.0	.0 mg
ORTHOPTERA	.1	1.7 mg	.0	.0 mg	.1	.9 mg	.0	.0 mg
PLECOPTERA	.9	4.2 mg	.0	.0 mg	.1	.2 mg	.0	.0 mg

Table 5. (Con'd.)

ORDER	1966 INSECT-CONTROL		1968 INSECT-CONTROL		DISTURBED		HIGHLY DISTURBED	
	Number	Weight mg	Number	Weight mg	Number	Weight mg	Number	Weight mg
PSOCOPTERA	1.2	.2 mg	.7	.0 mg	1.4	.1 mg	2.0	.2 mg
THYSANOPTERA	.3	.0 mg	.1	.0 mg	.1	.0 mg	.0	.0 mg
TRICHOPTERA	.7	.6 mg	.1	5.0 mg	1.0	2.8 mg	1.3	27.7 mg
INSECT FRAGMENTS	.1	.0 mg	.5	.0 mg	.3	.2 mg	.3	.1 mg
NON-INSECT ARACHNID	1.1	4.1 mg	.4	.1 mg	.9	.4 mg	.8	.0 mg
***TOTAL	27.6	16.2 mg	19.4	13.1 mg	71.3	21.7 mg	106.5	41.9 mg

1966 and 1968, showed a high probability (when compared by number and weight) of coming from the same type area, while the "Disturbed" and "Highly Disturbed" areas when compared to the 1968 "Insect-Control" area showed negligible probability. When grouped and tested by month the Wilcoxon's test showed similar results, indicating the variation between categories was not due to bias introduced by sampling time.

Thus, the probable explanation for the large differences in numbers and weights of insects p.s.d., is road construction and the associated disturbance of the environment. These environmental changes resulted in a great increase in numbers of insects present at the surface of the South Fork, Caspar Creek.

<u>Aquatic Derived Insects</u>

The families of insects represented in the drop collections can be grouped, on the basis of life history of member species, as follows: 1) families whose species pass through all life stages on land (Terrestrial habitat insects), 2) families whose species pass their immature life stages in or on water (Aquatic habitat insects), and 3) families in which some species are terrestrial in all stages while other species have aquatic immature stages (Unspecified habitat insects).

The numbers and weights of Aquatic and Terrestrial insects for the years 1966 and 1968 are plotted in Figure 7. The 1968 collection was found to contain five times the number of Aquatic insects p.s.d. as that collected in 1966. Likewise,

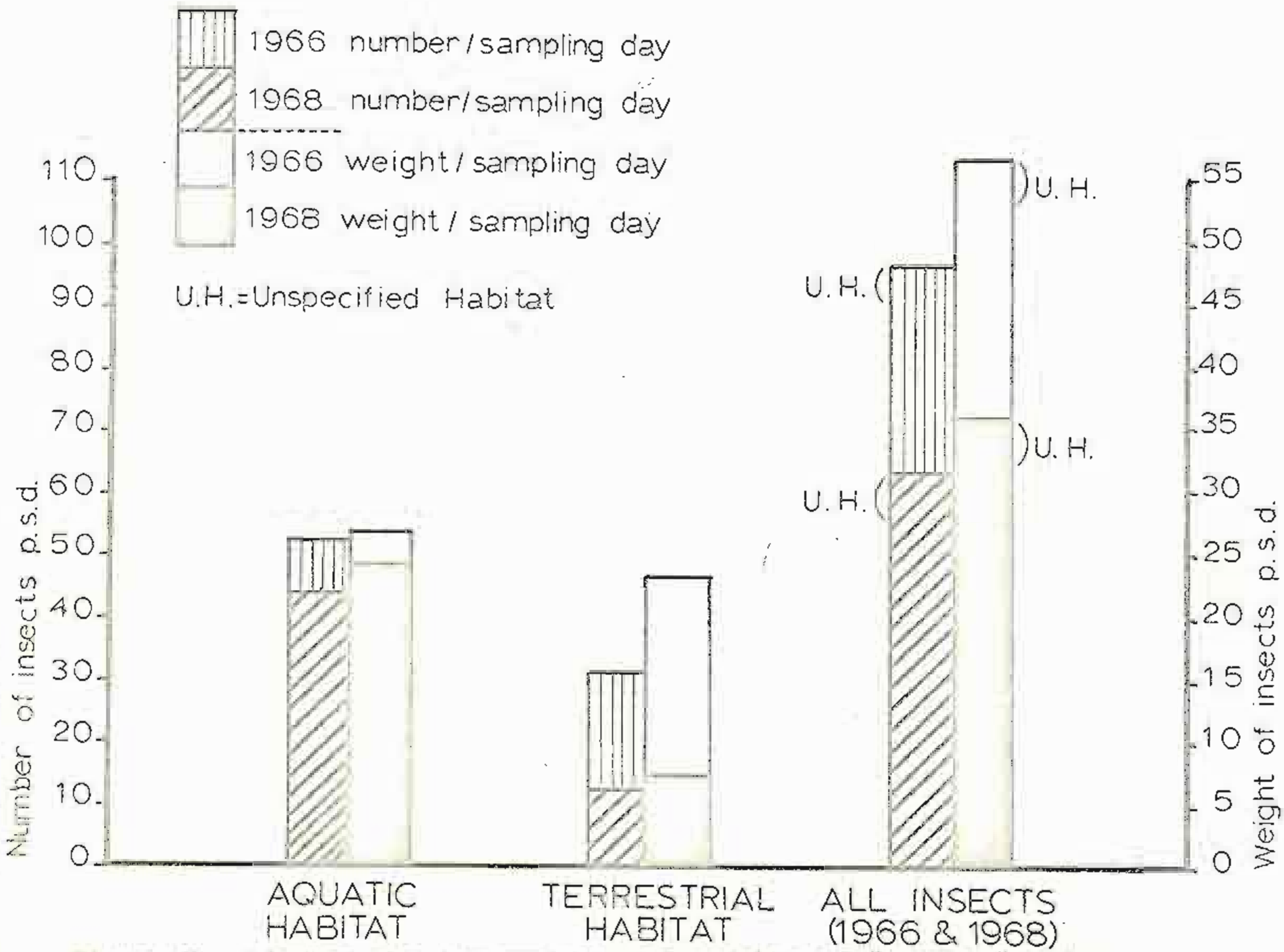

Figure 7. Diagram showing numbers and weights of "Aquatic" and "Terrestrial" habitat insects for 1966 and 1968.

in the 1968 collection, Aquatic insects were found to be ten times more important by weight. Terrestrial insects were found to show a one-third decrease in numbers and a one-half decrease in weight from the 1966 to 1968 collection.

The 38 groups plotted as Aquatic habitat insects, when compared to the 107 groups plotted as Terrestrial habitat insects, showed an interesting reversal. In 1966 there were twice as many Terrestrial insects as Aquatics, but in 1968 this reversed and Aquatics were three and one half times more prevalent.

The "Insect Controls", "Disturbed" and "Highly Disturbed" areas were employed to determine if this Aquatic increase was comparable to the degree of disturbance. Figure 8 shows that the 1966 and 1968 "Control" areas had similar numbers and weights of Aquatic habitat insects, while the "Disturbed" and "Highly Disturbed" areas showed large increases.

Thus, Aquatic habitat insects were much more abundant on the surface of the South Fork of Caspar Creek after road construction. The amount of disturbance also seems to affect the degree of this abundance.

Chironomid Increase

The most outstanding characteristic of the 1968 drop collection is the appearance of large numbers of chironomids. In 1966 they were present in the drop-collection at the rate of 2.2 individuals p.s.d., while in 1968 this increased to 34.5 chironomids p.s.d. This increase is very significant because this single family in 1968 contributed more insects

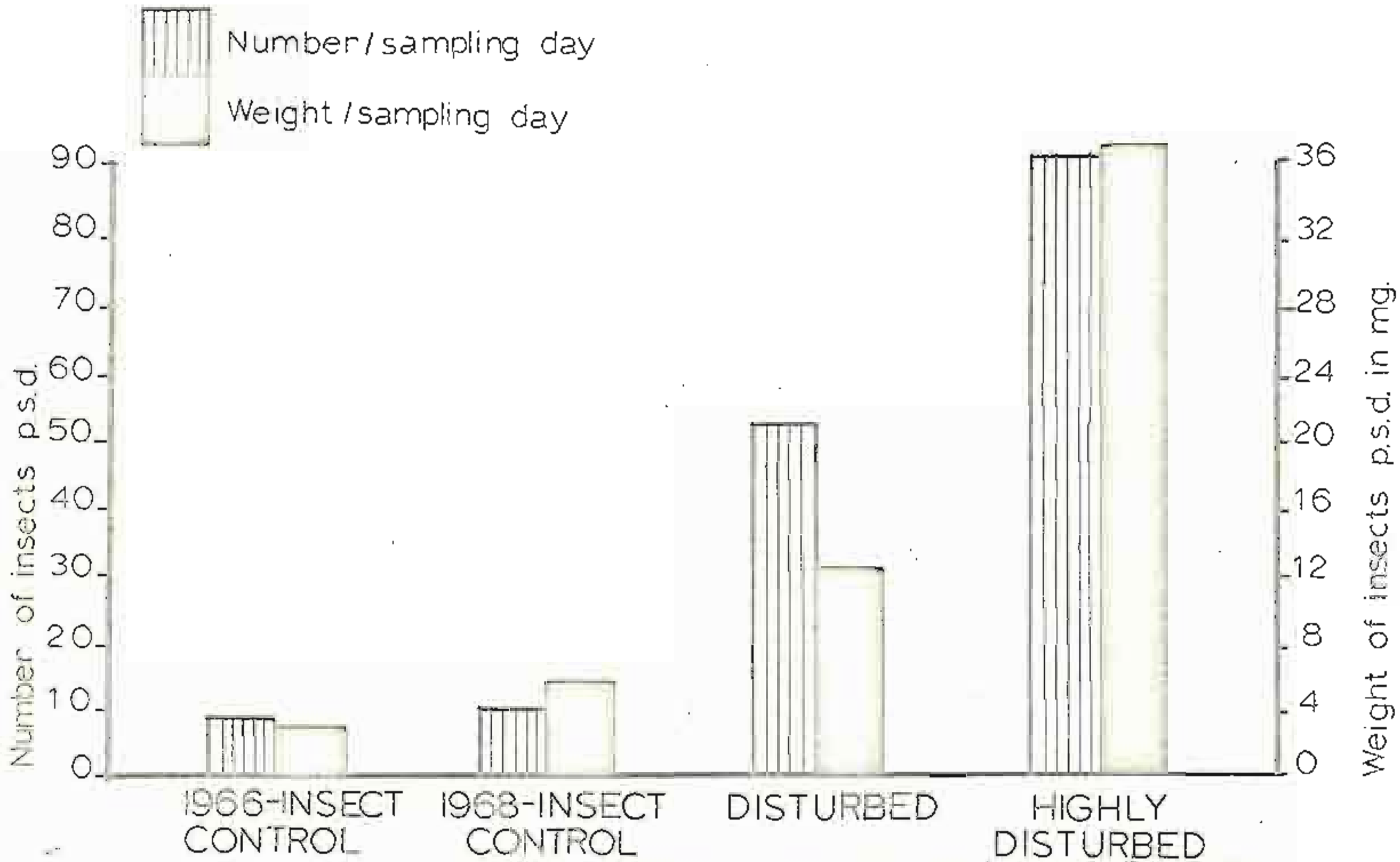

Figure 8. A histogram of the numbers and weights of "Aquatic" habitat insects for the 1966 Control, 1968 Control, Disturbed and Highly Disturbed areas.

p.s.d. to the collection (34.5 per day) than the total of all insect families in the 1966 collection (1966 rate 33.3 p.s.d.). In 1968 Chironomidae also exhibited numerical dominance over all families in both collections, having an eightfold advantage over the second highest occurring family, Ephydridae in 1966.

The reason for this dramatic increase seems to be the disturbance to the land surface, caused by building the logging road in 1967. The road construction caused immediate turbidities up to 4,000 p.p.m. during actual construction and turbidities in excess of 3,000 p.p.m. during the following winter (DeWitt, 1968). I believe silting of the stream killed most aquatic insects, except the more hardy Dipterans, especially chironomids, which thrive best in polluted, highly turbid conditions. Table 6 (Kopperdahl, personal communication), shows that during the summer of 1967 all aquatic insect orders increased in the "Undisturbed" North Fork of Caspar Creek while in the South Fork where the logging road was being built, only Diptera increased in the normal fashion, all other orders decreasing markedly. Therefore, by the end of road-building disturbance in 1967, the South Fork of Caspar Creek showed a greatly decreased insect population from what was expected, with the Diptera having a normal or somewhat greater population because of their ability to withstand high turbidities.

Chironomids, one of the best suited dipteran's for highly turbid conditions, have a short life cycle.

Table 6. California Fish and Game "Benthos Samples" from the Undisturbed North Fork and Disturbed South Fork of Caspar Creek. The June collections represent a pre-road sample while the October collections were made after south fork road completion.

ORDER	SOUTH FORK CASPAR CREEK Numbers per ft^2			NORTH FORK CASPAR CREEK Numbers per ft^2		
	June 1967	Oct. 1967	Difference (Oct.-June)	June 1967	Oct. 1967	Difference (Oct.-June)
COLEOPTERA	13.7	2.9	-10.8	3.6	4.6	+ 1.0
DIPTERA	40.1	104.2	+64.1	4.4	8.4	+ 4.0
EPHEMEROPTERA	38.9	15.4	-23.5	13.9	32.2	+18.3
PLECOPTERA	28.8	13.6	-15.2	13.3	26.9	+13.6
TRICHOPTERA	28.3	6.6	-21.7	12.0	38.1	+26.1
MISCELLANEOUS	1.8	0.3	- 1.5	0.3	0.5	+ 0.2

Therefore, with increased turbidities, chironomids were doubly favored because the South Fork was an open habitat in that most other insects had been eliminated by the silt, and their short life cycle enabled them to capitalize on this advantage. I presume chironomids increased by filling the niches left by the organisms driven out by pollution and by benefiting from the lack of normal competition and predation. The lack of competitors and predators is a highly significant factor for this family since it is on the bottom of many food chains. Thus, chironomids occuppied the most prominant position when the 1968 drop box collections were taken. The 1968 California Fish and Game Department's South Fork "benthos samples" also contain a large number of larval chironomids (Kopperdahl, personal communication).

Other hypotheses, however, have been offered to explain the above condition. Charles Warren (1964), in a paper on experimental stream enrichment implies that if removal of "forest canopy" can increase production of the bacterium Sphaerotilus natans, the principal food of chironomid larvae, chironomids in turn could increase phenomenally.

CONCLUSION

Insect populations, like fish, deer, rabbit and all other populations except man's, are constantly being affected by two forces, maximum carrying capacity of the habitat and habitat change.

An area, such as Caspar Creek, will support a certain biomass of insects, represented by a certain number of those insects. This number and biomass will fluctuate each year, but in an unaltered environment will eventually approach and maintain itself near a maximum carrying capacity. In the case of insects this habitat is composed of a number of niches each filled by a single species.

A logging road was constructed through this study area (1967), after which (1968) new measurements were made on the carrying capacity. The abundance of insect fauna in this area could have increased, decreased or remained unchanged. Of the niches that were present before the road was built, some remained unchanged and some have been altered or have even disappeared. Did the change in niche composition of the habitat also cause a change in insect composition? While this study dealt only with insects falling into a stream, definite changes can be seen in population composition within the scope of the study.

Analysed data from the entire "study area" show a two-fold increase in insects by number and weight after the logging road was built. The "Disturbed" areas show a fourfold increase by number and a 1.5 times increase by weight over the 1968 "Insect Control" area. The "Highly Disturbed" areas showed a fivefold increase by number and a threefold increase by weight over the "Insect Control".

A fivefold increase p.s.d. from 1966 to 1968 occurred in those adult insects that as immatures were associated with an aquatic environment.

If food was the limiting factor working upon the fish population, it is possible that the south fork would now support a larger population of fish due to the increase of drop insects.

It is probable that the changes summarized above are maximized at this point. As vegetation returns to this area, sediment flow decreases and the area starts its process of natural succession back to the undisturbed (original) state, the drop of insects into the South Fork of Caspar Creek should progressively decrease both by number and weight until a new balance is reached.

PERSONAL COMMUNICATION

Page	Source
40	DeWitt, John. Fisheries Department. Humboldt State College, Arcata, California.
9	Gossard, Samuel. Forester. Jackson State Forest, Fort Bragg, California.
48 & 50	Kopperdahl, Fredric. Asst. Water Quality Biologist. California Dept. of Fish and Game, Sacramento, California.

LITERATURE CITED

Arnett, Ross. 1968. The bettles of the United States. American Entomological Institute Press, Ann Arbor. 1112 pp.

Borror, Donald J. and Dwight M. DeLong. 1964. An introduction to the study of insects. Holt, Rinehart and Winston Press, New York. 819 pp.

Chapman, Donald W. 1966. The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. University of Pittsburg, Pymatuning Laboratory Symposia in Ecology. Spec. Publ. No. 4: 116-130.

Curran, C. H. 1965. The families and genera of North American Diptera. Henry Tripp Press, Woodhaven, N.Y. 515 pp.

Demory, Robert L. 1961. Foods of juvenile coho salmon and two insect groups in the coho diet in three tributaries of the Alsea River, Oregon. M.S. Thesis, Oregon State University. 68 pp.

DeWitt, John W. 1968. Caspar Creek ecology project, annual report 1967-68. Manuscript. 20 pp.

Dorn, Richard. 1969. Evaluation of air and water temperatures on Caspar Creek from 1965 to 1968. (Manuscript) Humboldt State College, Co-operative Fisheries Unit. 17 pp.

Kabel, C. S. and E. R. German. 1967. Caspar Creek study completion report. California Dept. Fish and Game, Marine Resources Branch Adminstration Report No. 67-4. 28 pp.

Peterson, Alvah. 1959. Larvae of insects, Part I. Edwards Brothers Press, Ann Arbor. 315 pp.

______. 1960. Larvae of insects, Part II. Edwards Brothers Press, Ann Arbor. 416 pp.

Raymond, F. H. 1964. Logging in redwood watersheds. California Resources Agency. 5 pp.

Steel, Robert G. and James H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, New York. 481 pp.

U. S. Forest Service, Pacific Southwest Forest and Range Experimental Station. Progress Reports: 1962, 1963, 1964, 1965, 1966, 1967, 1968.

Warren, Charles, et. al. 1964. Trout production in an experimental stream enriched with sucrose. Jour. Wildlife Mgt. 28(4): 617-660.

Wustenberg, Donald W. 1954. A preliminary survey of controlled logging on a trout stream in the H. J. Andrews Experimental Forest. Unpublished Master's Thesis, Oregon State College, Corvallis. 51 pp.

APPENDIX I

Value of Drop Box Samplers in Caspar Creek Study

The Caspar Creek study is the first recorded instance where drop-boxes have been used in any project of this type.

Drop-boxes as used in this project were designed to catch all insects and detritus falling on one square yard of stream surface. In this project drop-boxes were used only to evaluate insects dropping into a stream. Such boxes could also be used to evaluate terrestrial detritus or leaf enrichment of a stream, or moved away from the stream and used to predict insect drop, leaf fall, etc. under forest canopies.

Drop-boxes must not be confused with Surber samplers, drift samplers, or other stream samplers. Drop-boxes catch adult insects plus those immature terrestrial insects that would normally fall onto a stream surface. On the other hand the above mentioned samplers catch immature aquatic insects and those insects which drop into the stream and float in the water. Drop-box samplers thus deal with adult insects of both aquatic and terrestrial origin while other aquatic samplers deal principally with immature aquatic insects. Fish stomach analyses show a combination of the above two types of insects.

In the Caspar Creek study, investigators observed that drop-boxes were very efficient and caught all insects coming in contact with their surface. For method of placement, catching solutions, size of box etc. the reader is referred to the methods section of this paper.

Important facts were discovered on drop-box use during the study. It was found that drop-boxes should be placed high enough above the stream surface to prevent contamination from the stream due to increased stream flow. Furthermore, collecting solutions should contain formalin in addition to mineral oil because of its superior preserving qualities. Lastly and most important, all inner liners should be trimmed even with the drop-box which allows no overhang of the liner into the stream. If this condition exists contamination of samples can occur from a moisture gradient transport over the liner.